From the number of coincidences (which depends upon the amplitude discrimination of the pulses from a photomultiplier) we conclude that this new transition follows a β-decay with a maximum energy between 200 and 300 kev. This conclusion was confirmed by direct observation of the β-spectrum; the Fermi plot indicates a simple spectrum with an energy limit of (270±20) kev. From the intensity of the β-spectrum the following conversion coefficients for the 426-kev transition are deduced: $\alpha_L = (7.0\pm2.5)\times10^{-3}$ and $\alpha_{(M+N)} = (2.0\pm0.8)\times10^{-3}$. They are consistent with electric quadrupole radiation.

The K-conversion electrons of the new 426-kev transition have nearly the same energy as the L-conversion electrons which arise from the 354-kev radiation in the Pt-decay branch of Au^{196}. For that reason the K-conversion line could not be separated in the spectrum of the single counts, but it was revealed in the spectrum of coincidences. Here the intensity ratio for the two lines is more favorable, since every 426-kev transition immediately follows a β-ray, while the 354-kev radiation is only partly in coincidence with the weakly converted 332-kev radiation and a few Auger electrons. The measured energy difference of K- and L-shell conversion electrons confirms that the 426-kev transition occurs in the Hg-decay branch.

A detailed report and new data for the Pt-decay branch of Au^{196} will be published in *Helvetica Physica Acta*. We are indebted to Professor C. J. Bakker at Amsterdam for preparation of the radioactive samples, and to Professor P. Preiswerk for many helpful discussions.

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Regular Meson Potentials in Low Energy Proton-Proton Scattering*

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Although low energy proton-proton scattering can be explained quite well by a two-parameter system involving either a boundary condition on the wave function at a finite distance[1] or by means of potentials,[2,3] there exists a discrepancy between the mass of the meson used in the static approximation of meson theories; as, for example, that of Møller and Rosenfeld, by fitting to the experimental scattering results and the directly measured mass of the π-mesons believed largely responsible for nuclear forces. In using a potential of the form

$$\frac{\epsilon^2}{r}-\frac{Ce^{-r/a}}{r/a}, \qquad (1)$$

Yovits, Smith, Hull, Bengston, and Breit[3] obtained a mass of $m=\hbar/ac=333\pm2$ electron masses, whereas the masses of the π^+, π^-, and π^0 mesons are 277.4±1.1, 276.1±1.3, 264.6±3.2 m, respectively.[4,5] The accuracy in fitting the data is quite high and it seems that something additional is needed to explain the difference. The neutron-proton system seems to give a triplet interaction agreeing with the mass of meson theory, but the error is quite large in the singlet case.[6] A rough estimate of relativistic effects[7] for energies up to 4 Mev indicates that they may cause as much as a 2 percent decrease in the mass. Cutoffs by a straight line parallel to the axis at $r=\hbar/Mc$ where M is the proton mass indicate a meson mass slightly higher, and cutoffs at larger r's would make the mass even higher.

We have investigated the scattering up to 3 Mev, where it is to be expected effects of relativity would be least and angular momenta other than $L=0$ are not significant, by means of a potential form which satisfies certain basic requirements. We require that between protons the potential should be (1) asymptotically equal to the Coulomb potential, (2) finite everywhere, (3) derivable from the static approximation of a relativistically invariant meson theory. Condition (2) was imposed because the infinities associated with the Coulomb and meson potentials can have little physical significance. Condition (3) we required so that there would be some means of comparing the potential with theory.

The potential chosen for calculation,

$$(1-e^{-r/a_0})\left\{\frac{\epsilon^2}{r}-\frac{Ce^{-r/a}}{r/a}\right\}, \quad a_0=e^2/mc^2, \qquad (2)$$

which is a modification of (1) wherein the comparison of mass values is still possible, may easily be seen to satisfy the postulated requirements. We can consider (2) as consisting of a modified Coulomb term

$$\epsilon^2/r-\epsilon^2e^{-r/a_0}/r \qquad (3)$$

and a modified meson term

$$\frac{Ce^{-r/a}}{r/a}-\frac{Ce^{-(r/a+r/a_0)}}{r/a}. \qquad (4)$$

The exponential terms may then be considered as static meson potentials corresponding to different masses. Equation (2) could be easily generalized to bring in arbitrary meson masses so that the change in potential compared to (1) could be explained as being due to heavier mesons which introduce an interaction at short distances similar to that of Enatsu.[8] So as not to introduce a large number of parameters, however, we have restricted ourselves to C, related to the strength of the main meson term, and a, connected to the main meson mass.

The procedure used in relating the potential parameters to scattering results is somewhat similar to that of Breit and Hatcher.[7] Interior solutions were calculated out to $r=3e^2/mc^2$ by numerical integration and matched there to pure Coulomb solutions calculated from the formulas of Yost, Wheeler, and Breit[9] for a range of values of C and a. Values were obtained for the phase shifts and to test the error in neglecting the meson tails several calculations were performed out to $6e^2/mc^2$ where the phase shifts seemed to converge. To estimate analytically the error introduced, a modification of the Born approximation was employed which will be reported on in a forthcoming publication. Our results show that for a value of a corresponding to a meson mass of $274m$ agreement is obtained with experimental results. It is seen then that this theory is a possible explanation of the meson mass disagreement.

It is to be noted that other explanations of the discrepancy have recently appeared. Jastrow[9] has employed a repulsive core with some success, and Breit and Yovits[10] have suggested an internal excitation of the two-particle system which would lead to a possible change of about 10 percent.

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Inelastic Scattering Resulting in Short-Lived Isomers

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The angular distribution of the γ-radiation that follows an inelastic scattering process may either provide information concerning spin and parity of the involved levels, or if these data are known, prove the applicability of a certain nuclear model.

We assume that the target nucleus is heavy enough to remain at rest in the center-of-mass system. The z-axis is taken in the direction of the incoming particle. Then the γ-angular distribution, with the outgoing particle unobserved, is given by

$$W(\vartheta)=\sum_{LL'ii'\nu}(-)^{i_2-i_2'+L_1-L_2+L_3+\nu}(2i_3+1)^{\frac{1}{2}}(2i_3'+1)^{\frac{1}{2}}$$
$$\times(2i_2+1)(2i_2'+1)(2L_2+1)^{-1}c_\nu(L_1L_1')c_\nu(L_3L_3')$$
$$\times W(L_1i_2L_1'i_2',\, i_1\nu)W(i_2i_3i_2'i_3',\, L_2\nu)W(L_3i_3L_3'i_3',\, i_4\nu)$$
$$\times SL_2i_3,L_1i_1{}^{(i_2)*}SL_2'i_3',L_1'i_1'{}^{(i_2')}Ti_4,i_3{}^{(L_3)*}Ti_4,i_3'{}^{(L_3')}P_\nu(\cos\vartheta).$$

The numbers i_1 to i_4 mean the level spins of the target nucleus, the compound nucleus, the residual nucleus of the scattering process, and the final nucleus which later may coincide with i_1 except for its orientation. The L's are the total angular momenta of the incoming and the outgoing particle and the γ-radiation. The S-matrix elements are the radial parts of the probability amplitudes of the inelastic scattering, i.e., they are independent of magnetic quantum numbers. The relative probability of the γ-radiation is signified by $Ti_4,i_3{}^{(L_3)}$. The W's are the Racah coefficients.[1,2] The c_ν's are defined by

$$c_\nu(LL)=\Sigma_\mu(-)^{L'-\mu}(LL'-\mu\mu|\nu 0),$$

where μ is the z-projection of the particle spin and $(LL'-\mu\mu|\nu 0)$ is a Clebsch-Gordan coefficient. The triangular relations of the Racah coefficients restrict the degree of the Legendre polynomials $P_\nu(\cos\vartheta)$ to values $\leq(L+L',\, i_2+i_2',\, i_3+i_3',\, L_3+L_3')$.

The given expression for $W(\vartheta)$ describes the process with full generality. Without making further assumptions about the levels involved and the nature of the transitions, it cannot be simplified any further. In the case when the inelastic scattering process results in a short-lived isomer[3] with mass number >100, two essential simplifications seem to be possible. The γ-transition will, in general, be a pure multipole. Therefore, the product of the radiative transition probabilities $Ti_4,i_3{}^{(L_3)}$ can be dropped as a common factor. Furthermore, the statistical assumption[4] may be made for the compound nucleus of the scattering process which cancels interference terms and replaces the product of the S-matrix elements by the transmission for the incoming particle. Using channel spins for the scattering process, we get then for the γ-angular distribution

$$W_E(\vartheta)=\sum_{lji\nu}(-)^{l_2}Tl_1(E)(2i_2+1)^2(2l_1+1)^2(2l_2+1)^{-1}$$
$$\times(l_1l_100|\nu 0)(L_3L_3-11|\nu 0)W(l_1i_2l_1i_2,\, j_1\nu)$$
$$\times W(i_2j_3i_2j_3,\, l_2\nu)W(L_3i_3L_3i_3,\, i_4\nu)P_\nu(\cos\vartheta),$$

where E is the energy of the incoming particle and $Tl_1(E)$ is its transmission.[4]

Since odd Legendre polynomials in $W(\vartheta)$ arise from interference terms, the first requirement for the applicability of the formalism is the symmetry of the angular distribution.

We assume that the inelastic scattering that leads to the isomeric states listed below is neutron scattering. Then the coefficients for the Legendre polynomials of the angular distribution are given in Table I. Proton scattering or scattering of other particles would express itself in changed transmissions $Tl_1(E)$.

TABLE I. The coefficients of the γ-angular distribution $W_E(\vartheta)=P_0+a_2P_2(\cos\vartheta)+a_4P_4(\cos\vartheta)$. E is the energy of the incoming neutron; i_1 and i_4 are the spin numbers of the target and the final nucleus; i_3 is the one of the isomeric level.

Target nucleus	Isomeric level (kev)	E (kev)	i_1, i_4	i_3	a_2	a_4
Cd^{111}	247	330	$\frac{1}{2}+$	$\frac{5}{2}+$	−1.26	0.007
Er^{166}	80	170	$0+$	$2+$	1.07	0
Yb^{170}	84	170	$0+$	$2+$	1.07	0
Ta^{181}	134	210	$\frac{3}{2}+$	$\frac{1}{2}+$	0	0
Ta^{181}	345	430	$\frac{7}{2}+$	$\frac{3}{2}+$	−1.99	0
Os^{186}	137	220	$0+$	$2+$	−0.026	0.348
Hg^{197}	133	220	$\frac{1}{2}-$	$\frac{5}{2}-$	−0.279	0.006
Pb^{204}	374	450	$0+$	$2+$	0.071	1.27

The energy of the incoming neutron was chosen to be about 80 kev above the threshold. This means that l_2 is restricted to the values 0 and 1. Higher energies would quickly increase the number of l-values and would complicate the computation of $W_E(\vartheta)$ considerably.

Since the spin and parity assignments are well established by other experiments, an experimental check of the given angular distributions would show how well the statistical model accounts for the given situation.

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Internal Absorption of Fluorescent Light in Large Plastic Scintillators*

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THE preparation and performance of comparatively small plastic scintillators have been reported by several authors.[1–3] We have made some plastic scintillators of large dimensions by impregnating styrene monomer with various fluorescent substances before polymerization. No catalyst was used in the process. In a series of experiments, the samples had the form of a cylindrical rod 3.5 cm in diameter and 20 cm long. The pulse sizes were observed in an oscilloscope from the output of a 5819 photomultiplier attached to one end of the rod. Except for this end, the rod was wrapped with 0.133-mm thick aluminum foil as a reflecting surface in order to improve light collection. A narrow beam of γ-ray from a Co^{60} source passed through the rod perpendicularly to its axis at various distances from the surface of the photomultiplier. The results are summarized in Table I. Cosmic rays from a coincident counter telescope and a soft x-ray beam from a dental machine were also used as sources of irradiation and gave similar results. From the table we can see that there is little internal absorption of fluorescent light in the cases of a and c, while b shows considerable absorption at greater lengths. The concentration of the anthracene in polystyrene was about 3 percent. No great difference in internal absorption was observed in varying the concentration from 2–5 percent. The concentration of p-terphenyl in polystyrene was about 2 percent. The addition of about 0.01 percent diphenylhexatriene made no significant difference in the large internal absorption as shown in Table I. When the concentration of p-terphenyl was raised to 4 percent, some part of the plastic became less transparent in appearance. In the table the results for liquid phenylcyclohexane solution (plus 0.3 percent p-terphenyl and 0.001 percent diphenylhexatriene) of the same dimensions as the plastic rods are also included. An anthracene crystal 3 cm in diameter and 3.3 cm in length was also used and gave a pulse size of 5.4 (in the same units as used in Table I). A plastic scintillator consisting of 3 percent anthracene in polystyrene, 4.1 cm in diameter and 30 cm long (this is the maximum length that has been investigated), showed relatively small absorption (less than 15 percent) of the light output throughout the

TABLE I. Pulse sizes (in arbitrary units) observed with a Co^{60} source.

	Phosphor	Distance of the path of radiation through the sample from the surface of the photomultiplier: 1 cm	10 cm	20 cm
a	Anthracene in polystyrene	0.6	0.5	0.5
b	p-terphenyl in polystyrene	1.4	0.8	0.5
c	Phenylcyclohexane solution	1.6	1.6	1.5